3/8R7S

10/511393

DT05 Rec'd PCT/PTO 1 5 OCT 2004,

ENGLISH TRANSLATION

WO 03/87560

PCT/DE03/01168

1

Description

Device for determining fuel quality and corresponding
method

The invention relates to a device for determining the
quality of fuel for an internal combustion engine as
claimed in claim 1 and a corresponding operating method
as claimed in claim 6.

The quality of the fuel used to drive internal combustion
engines may be subject to manufacturing tolerances, for
example the fuel may contain varying proportions of long-
chain hydrocarbons.

It is therefore a well-known procedure to determine the
quality of the fuel used and to take this into account in
the fuel injection process in order to compensate for the
quality variations as far as possible.

At present, variations in fuel quality are detected using
a starting-quantity adaptation technique or the uneven-
running method, and compensated for by varying the
injection periods. In these known methods, the increase
in speed when starting the internal combustion engine or
the speed variations at start-up are evaluated. If the
increase in speed or the speed variations lies/lie
outside an allowed preset confidence band the injection
period is corrected accordingly. The correction amount is
calculated relatively imprecisely, however, so that
sometimes the correction proves too great. In particular,
given a "poor start", the injection period is changed so
as to make the fuel-air mixture richer, which means that
the fuel-air mixture may be too rich after filling up

with a very good quality fuel. The internal combustion
engine then only starts badly or not at all.

Another disadvantage of this method for determining the
fuel quality is the relatively low accuracy, because the
increase in speed when starting the internal combustion
engine does not depend solely on the fuel quality but is
also affected by other parameters such as the internal
friction of the internal combustion engine.

DE 40 27 947 A1 describes various ways in which one can
take into account fuel quality variations. One way is to
measure the control deviation in the lambda control
circuit after each tank fill of the vehicle driven by the
internal combustion engine, and to vary an adaptation
value so as to reduce the control deviation to zero. This
method has the disadvantage that it only works when the
lambda control system is enabled. This is specifically
not the case, however, when the internal combustion
engine is cold. Other methods are proposed that ensure
that, even when the internal combustion engine is cold,
the internal combustion engine is still able to run when
the fuel composition changes sharply at tank fill-up, for
instance when a tank containing fuel is practically
emptied and then filled with a fuel containing mainly
methanol. Using the tank levels before and after tank
fill, an assessment of what sort of fuel compositions can
be present is made on the basis of commercial fuel data.
The input control values are then modified for running
the internal combustion engine using fuels of the
possible compositions, and the system assesses which
composition the internal combustion engine runs best
with. These values are used from then on for controlling
the internal combustion engine.

The disadvantage of these known methods for determining the fuel quality, however, is that they are coupled with the combustion process and hence may also be affected by other parameters.

5

It is therefore the object of the invention to define a device independent of the combustion process and a corresponding method for determining the fuel quality.

10   The object is achieved with regard to the device by the features of claim 1, and with regard to a corresponding method by the features of claim 6.

The invention is based on the technical knowledge that
15   the fuel quality can be assessed from its gas emission behavior. For instance a fuel containing a high proportion of long-chain hydrocarbons has a weaker gas emission than a fuel containing a high proportion of short-chain hydrocarbons, because long-chain hydrocarbons
20   are less volatile. The gas emission behavior of the fuel therefore reflects the long-chain and short-chain hydrocarbon composition of the fuel and hence the fuel quality.

25   It is therefore provided within the invention to measure the pressure and/or temperature in a fuel container in order to derive from this a quality value that represents the fuel quality.

30   The pressure or temperature in the fuel container is preferably measured by a separate pressure sensor or temperature sensor respectively. Alternatively, however, the pressure and/or temperature in the fuel container may be derived from other measured values, avoiding the need
35   for a separate pressure and/or temperature sensor. The

term used in the context of the invention for a pressure
and/or temperature sensor should therefore be understood
as a general term covering all arrangements in which the
pressure and/or the temperature in the fuel container is
5    measured directly or indirectly. For example, the
temperature sensor may also measure the fuel temperature
in the low-pressure section of the injection system in
order to derive the fuel temperature in the fuel
container.
10

In addition, the device according to the invention
contains an evaluation unit whose inputs are connected to
the temperature sensor and/or the pressure sensor, and
which determines the quality value as a function of the
15   pressure and/or temperature in the fuel container.

The evaluation unit preferably contains two processing
units, where the first processing unit is connected to
the pressure sensor and the temperature sensor and
20   determines a gas emission characteristic value
representing the gas emission behavior of the fuel as a
function of the pressure and temperature in the fuel
container.

25   The second processing unit then determines the quality
value of the fuel on the basis of the gas emission
characteristic value, the gas emission characteristic
value preferably being linked to the quality value
according to a functional relationship. The second
30   processing unit may also be a characterizer, however, in
which this functional relationship is stored in the form
of a table.

The evaluation unit preferably contains a differentiator
35   which determines the rate of change in pressure in the

fuel container. The term differentiator, however, should be understood in its general sense in the context of the patent, and covers not only differentiation in the narrow mathematical sense, but also components or sub-assemblies
5   that measure the rate of change in pressure.

In the preferred embodiment of the invention, a comparator unit is also provided, which compares the rate of change in pressure in the fuel container with a preset
10  threshold value. This procedure is based on the knowledge that the gas emission behavior of the fuel is highly temperature-dependent and exhibits an abrupt change at a specific threshold temperature. In fact when the temperature exceeds the threshold temperature, the fuel
15  gas emission increases abruptly, which accordingly causes an abrupt rise in pressure in the fuel container when the fuel warms up. In the opposite situation, during cooling, the pressure in the fuel container drops abruptly when the temperature falls below the threshold temperature.
20  Thus in order to be able to determine the threshold temperature as the gas emission characteristic value, the preset threshold value for the change in pressure preferably equals the change in pressure at the preset threshold temperature.
25
Finally, in the preferred embodiment of the invention, a sample-and-hold device is provided, which is triggered by the comparator unit to store temporarily the temperature currently measured in the fuel container when the current
30  change in pressure in the fuel container exceeds the preset threshold value. In this way the sample-and-hold device always holds the threshold temperature at which the fuel abruptly changes its gas emission behavior.

The method according to the invention for determining the fuel quality can also be implemented as a computer program, for instance by suitable modification of the control program in the electronic control unit of an injection system. The device according to the invention can accordingly be fully integrated in the electronic control unit of an injection system.

It is also possible, however, to design the device according to the invention as a separate sub-assembly, which can then be connected via data lines to the electronic control unit of the injection system.

In addition, it should be mentioned that the method according to the invention can be implemented both after the internal combustion engine is switched off when the fuel is cooling and while the internal combustion engine is running when the fuel is warming up. The only crucial factor is that the gas emission behavior of the fuel in the fuel container varies according to the temperature, which enables an assessment of the fuel composition.

An advantage of the device according to the invention and the corresponding method is the relatively low cost, because conventional injection systems usually already have a temperature sensor for measuring the fuel temperature.

Other advantageous developments of the invention are characterized in the subclaims or are explained in more detail below in the description of the preferred exemplary embodiment of the invention with reference to the drawings, in which:

Figure 1                    shows a device according to the
                            invention for determining the fuel
                            quality,

5   Figure 2                    shows the operating method of the device
                            of Figure 1 as a flow diagram, and

Figure 3a and 3b show a cooling and heating curve for the
                            fuel

10

The device according to the invention shown in Figure 1
is used for determining the quality of the fuel in a fuel
container of an internal combustion engine and enables
the determined fuel quality to be taken into account when
15  running the internal combustion engine, for example by
controlling an injection system accordingly.

The determination of the fuel quality according to the
invention is based on the knowledge that the gas emission
20  behavior of the fuel depends on the fuel quality, because
long-chain hydrocarbons have a weaker gas emission than
short-chain hydrocarbons. For a standard composition of
the fuel containing a defined proportion of long-chain
and short-chain hydrocarbons, the fuel therefore has a
25  defined gas emission behavior, while deviations in the
fuel composition from the standard are associated with a
modified gas emission behavior.

The gas emission behavior of the fuel is in this case
30  measured on the basis of the fuel held in the fuel
container, the fuel container being closed off during the
measurement so that the fuel gas emissions result in a
measurable pressure change.

Thus the device according to the invention contains a pressure sensor 1, which is arranged in the wall of the fuel container and measures the pressure difference $\Delta p$ between the internal pressure $p_{Internal}$ in the fuel container

5   and the ambient pressure $p_{External}$.

In addition, another pressure sensor 2 is provided, which measures the ambient pressure $p_{External}$ so that altitude or weather-related changes in the ambient pressure $p_{External}$ can

10  be taken into account. The pressure sensor 2 may be a conventional sensor in the narrower sense, but it is also possible for the ambient pressure $p_{External}$ to be derived from other measured values.

15  The outputs of the two pressure sensors 1, 2 are connected to a processing unit 3, which calculates the internal pressure $p_{Internal}$ in the fuel container from the pressure difference $\Delta p$ and the ambient pressure $p_{External}$.

20  The gas emission behavior of the fuel does not depend solely on the long-chain and short-chain hydrocarbon composition of the fuel however, but also on the fuel temperature, because as the fuel temperature increases more gas is emitted by the fuel, leading to a

25  corresponding increase in pressure.

The device according to the invention therefore additionally contains a temperature sensor 4, which is also arranged in the wall of the fuel container and

30  measures the fuel temperature.

The outputs of the processing unit 3 and the temperature sensor 4 are connected to an evaluation unit 5, which determines a quality value Q representing the fuel

quality from the measured values for pressure p and temperature T.

The evaluation unit 5 contains a processing unit 6 for
5    this purpose, which determines the rate of change dp/dt in the pressure difference p measured by the pressure sensor 1.

The output of the processing unit 6 is connected to a
10   further processing unit 7, which determines the absolute value of the rate of change in pressure. This is necessary because the rate of change in pressure dp/dt is negative when the fuel is cooling after switching off the internal combustion engine, as shown in Figure 3a. In
15   contrast, the rate of change in pressure dp/dt is positive when measured after starting up the internal combustion engine, as shown in Figure 3b.

The output of the processing unit 7 is connected to a
20   comparator unit 8, which compares the absolute value of the rate of change in pressure dp/dt with a preset threshold value $dt/dt_{MIN}$.

This makes use of the knowledge that the fuel gas
25   emission behavior is highly temperature-dependent, which results in an abrupt pressure change at a specific threshold temperature $T_{TH}$, as can be seen in Figure 3a and 3b. In this case the preset threshold value $dp/dt_{MIN}$ is substantially equal to the rate of change in pressure at
30  the threshold temperature $T_{TH}$, so that the comparator unit 8 enables the threshold temperature $T_{TH}$ to be determined.

The threshold temperature $T_{TH}$ is not constant, however, but
35   depends on the fuel composition and reflects the gas

emission behavior of the fuel. A low threshold value $T_{TH}$ is an indicator of a highly volatile fuel containing a high proportion of short-chain hydrocarbons. A high threshold value $T_{TH}$, on the other hand, results from a

5    high proportion of long-chain hydrocarbons, which means that the fuel is less volatile. The threshold value $T_{TH}$ is hence a gas emission characteristic value that reflects the gas emission behavior of the fuel.

10   Depending on the comparison result, the comparator unit 8 triggers a sample-and-hold device 9, whose input is connected to the temperature sensor 4. If the rate of change in pressure dp/dt exceeds the preset threshold value $dp/dt_{MIN}$, the sample-and-hold circuit 9 accepts and

15   stores as the threshold temperature $T_{TH}$ the temperature T currently being measured. Otherwise the sample-and-hold device 9 retains the previously measured value for the threshold temperature $T_{TH}$.

20   Finally, the sample-and-hold device 9 is connected to a processing unit 10, which calculates the quality value Q representing the fuel quality from the stored gas emission characteristic value $T_{TH}$. The quality value is calculated according to a defined functional

25   relationship, which is saved in the form of a table in the processing unit 10.

An injection system for an internal combustion engine can then take into account the quality value Q determined by

30   the device according to the invention in order to compensate for the effects of a varying fuel quality.

The method according to the invention is described below with reference to the flow diagram shown in Figure 2.

35

After the start, the temperature T and the internal pressure $p_{Internal}$ in the fuel container of the internal combustion engine are measured continuously in a loop.

5  The pressure gradient dp/dt is also calculated continuously and the absolute value of the pressure gradient determined continuously.

The absolute value of the pressure gradient is then
10  compared - continuously with the preset threshold value $dp/dt_{MIN}$, this being the rate of change in pressure that occurs during the abrupt change in the fuel gas emission behavior at the threshold temperature $T_{TH}$, corresponding to the time $t_{TH}$ in Figures 3a and 3b.
15

If the pressure gradient dp/dt exceeds the preset threshold value $dp/dt_{MIN}$, the current temperature T is stored as the threshold temperature $T_{TH}$. Otherwise the process continues in the loop until the current pressure
20  gradient dp/dt exceeds the threshold value $dp/dt_{MIN}$.

In a final step, the quality value Q representing the fuel quality is then calculated from the stored threshold temperature $T_{TH}$ according to a defined functional
25  relationship. The injection system can then take into account this quality value Q in order to compensate for the effect of a varying fuel quality.

The method according to the invention described above
30  works both as the fuel is cooling after switching off the internal combustion engine and when the engine is running with the fuel warming up slowly.

Figure 3a shows the behavior of the temperature T and the
35  pressure p in the fuel container as the fuel cools after

switching off the internal combustion engine, when the temperature T declines exponentially. The pressure p also follows the downward temperature curve, but the pressure curve exhibits an abrupt drop at the time $t_{TH}$, when the temperature falls below the threshold temperature $t_{TH}$. The reason for this is that the fuel gas emission behavior is highly temperature-dependent and emission sets in at the threshold temperature $T_{TH}$. The threshold temperature $T_{TH}$ thus constitutes a gas emission characteristic value representing the gas emission behavior of the fuel.

Figure 3b, on the other hand, shows the behavior of the temperature T and the pressure p in the fuel container after starting up the internal combustion engine, when the fuel temperature T increases exponentially. The pressure p in the fuel container also increases with the temperature, and exhibits an abrupt rise when the temperature exceeds the threshold temperature $T_{TH}$. The reason for this is that the fuel gas emission behavior increases abruptly when the threshold temperature $T_{TH}$ is exceeded, so that the threshold temperature $T_{TH}$ constitutes a gas emission characteristic value representing the fuel gas emission behavior that is not temperature-dependent.

The invention is not restricted to the exemplary embodiment described above, but one can think of a multiplicity of variations and modifications that also make use of the idea of the invention and hence fall within the scope of protection.